Effects of Occupational Exposures on Cancer Mortality in the Mayak Worker Cohort

- Scientific Implications
- Recent results
- Future directions

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Scientific Impact and Implications

- **Demonstrated effects of chronic occupational radiation exposures from inhaled Pu aerosols on lung, liver, and bone cancer rates with no evidence of effects on other malignancies.**
- **Demonstrated effects of external gamma exposure on lung, liver, other solid cancer, and leukemia rates.**
- **Developed statistical methods and risk models:**
  - Use a combination of pre-monitoring Pu exposure surrogates and post-monitoring dose estimates for Pu risk estimation.
  - Time-dependent effect modifiers for chronic exposures (age, age at exposure)
  - Manage and use Monte-Carlo dose realizations to allow for dose uncertainty effects on risk uncertainties
- **Provided risk estimates for external gamma and internal alpha exposures that can be used for radiation protection and other uses.**

Recent Findings: Leukemia and Liver Cancer Mortality in the MWC

- **Cohort description**
  - 27,757 workers (25% female)
  - Follow-up from 1948-2015 with 998,055 person-years of follow-up
  - Deaths
    - Leukemia: 96 non-CLL deaths and 21 CLL deaths
      - 40 AML, 18 CML, 1 ALL, and 37 other/NOS
    - Liver cancer: 93 deaths
      - 21 workers with no Pu exposure and 29 workers with Pu dose estimates

Recent Findings: Leukemia and Liver Cancer Mortality in the MWC

- **Dosimetry**
  - 500 realizations of individual annual external doses from MWDS-2013 dosimetry
  - 1000 realizations of individual annual internal (Pu) doses from MWDS-2016 based on urinalysis activity measurements
    - Only post-monitoring dose estimates are used for Pu dose-response analyses
    - Pu surrogate exposure categories used for pre-monitoring period
  - Primary analyses based on mean of the individual annual dose realizations

Recent Findings: Leukemia Mortality in the MWC

- **No indication of Pu effects on non-CLL leukemia rates**
  - Examined using both marrow and liver dose estimates
  - Consistent with earlier findings
- **Quadratic external ERR dose response with attained age effect modification**
  - ERR per Gy^2 0.25 (95% CI (0,04; 0.7) at age 60
  - Rapid decreasing ERR with increasing age at death proportional to $\frac{1}{age^{4.4}}$

Recent Findings: Leukemia Mortality in the MWC

- **Significant time since exposure effect with further modification by age at death**
  - Quadratic dose response in three time-since –dose-received windows

Exposure period years before death	ERR/ Gy^2	95% CI
0 - 2	1.47	(0.06; 11)
2 – 5	2.45	(0.33; 12)
5+	0.28	(0.06; 0.72)
Dose Effect Modificaiton		
Attained age power	-3.05	-6.23; -0.59

	Non-CLL death?		Total	*Case/non-case mean dose ratio*
	No	Yes		
People	25,661	96	**25,757**	
	Mean dose (mGy)			
Time-since exposure-window				
0 - 2	6.4	61.2	6.6	*9.60*
2 - 5	8.6	186.9	9.3	*21.70*
5+	337.6	689.3	338.9	*2.00*
Total Dose	352.6	937.4	354.8	*1.40*

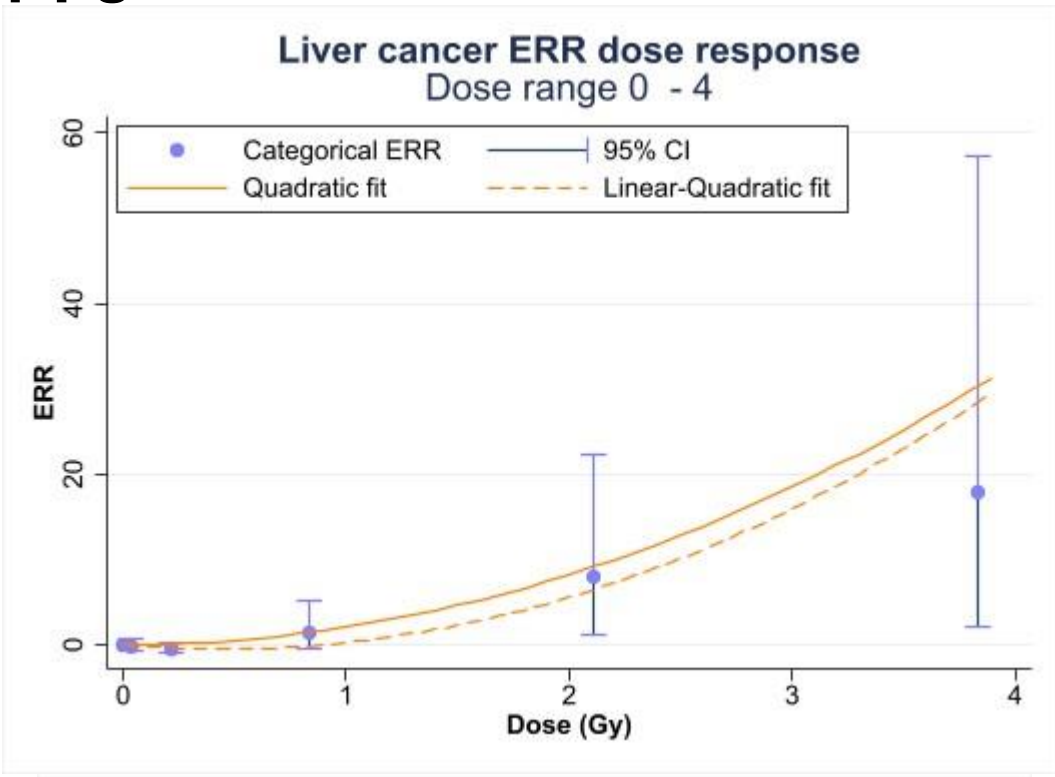
  - ERRs associated with recent doses received within 5 years of death are considerably larger than those received 5 or more years before death
    - Statistically significant effect for doses received within two years of death

Recent Findings: Liver Cancer Mortality in the MWC

- **Significant linear external dose effect – ERR/Gy 0.45**
- **Highly non-linear dose-response for Pu**

Dose Category (Gy)	Person years	Liver Cancer		ERR
		Deaths	Cases per 10,000 PY	
exposed unk dose	576,461	44	0.76	---
0	330,169	22	0.67	0
0 - 0.1	56,763	6	1.06	-0.20
0.1-0.5	25,940	2	0.77	-0.57
00.5-1.5	5,969	3	1.2	1.4
`1.5-3	1,779	3	9.0	8.0
3-5	548	2	65	18
5-10	361	6	166	94
10+	61	5	820	535
Total	998,050	93	0.93	

- Quadratic dose response ERR/Gy^2 2.15



Future Work

- **Dosimetry**
  - Finalize JEM dosimetry Pu
- **Risk estimation**
  - Extended follow-up
  - Non-cancer mortality analyses
  - JEM-based Pu dose-response analyses for lung, liver, and bone cancers
  - Updated external exposure cancer dose-response analyses
- **Analytical methods**
  - Further development of dose uncertainty adjustment methods

MWC Mortality Projections

- **Current follow-up through 2015**
  - 10% of male and 15% of cohort members alive and not lost to follow-up

Cause of death	Deaths at EOF			%change to 2025		
	Male	Female	Total	Male	Female	Total
Non Cancer	8,630	2,360	10,990	21%	33%	24%
Lung, Liver Bone	913	133	1,046	18%	16%	18%
Other solid cancer	1,587	597	2,184	36%	50%	40%
Non-CLL	75	21	96	6%	19%	9%
Other Hematopoietic	76	31	107	38%	55%	43%
Total Deaths	11,281	3,142	14,423	23%	36%	26%
Surviving cohort members	3,786	1,773	5,559	-32%	-36%	-33%

  - 22% of cohort members were alive now in 2016, about 11% now and 7% in 2030

Period	Status	Male	Female	Total
2016	Alive	3,786	1,773	5,559
Deaths 2016-2024	Non Cancer	1,302	572	1,875
	Lung, Liver Bone	122	16	138
	Other solid cancer	413	214	627
	Non-CLL	3	3	6
	Other Hematopoietic	20	12	32
	Total Deaths	*1,860*	*818*	*2,678*
2025	Alive	1,926	955	2,881
Deaths 2025-2029	Non Cancer	496	218	713
	Lung, Liver Bone	41	5	46
	Other solid cancer	162	83	244
	Non-CLL	1	1	2
	Other Hematopoietic	*9*	*5*	*13*
	Total Deaths	*708*	*311*	*1,019*
2030	Alive	1,217	645	1,862